FUNDAMENTALS AND APPLICATION OF MICROTOMOGRAPHY

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Abstract

The word «tomography» can be translated from the Greek as «slice of image». This means that the appointment of tomography is obtaining cross-sectional images of the internal structure of the object of the study.

Attenuation - reduction in the intensity of X-rays passing through matter, the degree of attenuation is expressed quantitatively by the linear attenuation coefficient;

Detector – tomography component measuring the intensity of the incident X-rays. Usually scanners equipped with solid-state detectors or ionization chambers, effectively absorbing X-rays;

Geometry scanner - layout of X-ray tube and the detector relative to the axis of rotation;

Linear attenuation coefficient - x-ray attenuation coefficient;

Pixel – picture element;

Projection angle - the angle at which resides Source X-ray attenuation in the measurement of the profile;

Reconstruction image - calculation of image projection data;

X-ray tube - X-ray source used almost in all scanners. Consists of an anode and a cathode, placed in a vacuum chamber. The spectrum of the intensity of the generated radiation depends on the applied voltage and current to anode and to cathode, which is generated due to the fact that the electrodes leave the cathode and fall to the surface of the anode.

Introduction

Types of tomography:

1. Anatomical imaging , breaking tomography - is based on the physical implementation of sections of the test organism with subsequent fixation by chemicals , with further recording them on film . Classic examples are the Pirogov anatomical imaging slices and images of histological preparations. To maintain the shape of the body when the slicing, body is fixed, for example, by freezing.
2. Reconstructive tomography, noninvasive imaging - getting one way or another about the distribution parameter of interest in higher-dimensional object from its projections of lower dimension without destroying the object; antonym of anatomical imaging. In the scope of the concept includes computing and analog reconstructive tomography.
3. Analog reconstructive tomography - reconstructive tomography, which uses analog computing devices to restore the distribution parameter object.[2]

Computed tomography (CT) is a non-destructive technique that provides three-dimensional images of the internal structure of an object. The basic idea of this imaging technique goes back to J. Radon, who proved in 1917 that an n-dimensional object can be reconstructed from its (n-1)-dimensional projections. The possibility of non-invasively imaging three-dimensional sections of a human body was of such importance that Cormack and Hounsfield were awarded with the Nobel Price for Medicine in 1979.[3]

Micro computed tomography is X-ray imaging in 3D, by the same method used in hospital CT scans, but on a small scale with massively increased resolution. It really represents 3D microscopy, where very fine scale internal structure of objects is imaged non-destructively.

Classification of tomography:

From the viewpoint of relative position of the probe radiation source, object and detector, tomographic techniques may be divided into the following groups:

- Transmission - recorded probing external radiation passing through the passive (nonradiative) to partially weakening (the shadow of the object);
- emission - recorded radiation from active (radiative) object with a certain spatial distribution of radiation sources ;
- combined transmission-emission - recorded from secondary radiation sources distributed over the volume of the object and excited by external radiation ;
- ehoprobing - probing external radiation is recorded, which is reflected from the internal structures of the passive object.

Dimensions of the objects:

- Micro level (microtomography) - objects the size of a single cell is studied.
- Object level commensurate with the human body (as a separate body or laboratory mouse to the aircraft).
- Macro level - atmospheric phenomena, planets, stars.[2]

The MicroCT Technique

The basic physical principal of computed tomography is the interaction of ionizing radiation, such as X-ray with matter, where, in the energy range typically used for CT imaging, the so-called photo-effect builds the main interaction mechanism. The photo-effect attenuates the photons proportional to the third power of the order number of the elements and inverse proportional to the third power of the photon energy. Thus, the actual attenuation not only depends on the material but also on the energy spectrum of the X-ray source. As an X-ray beam penetrates an object, it is exponentially attenuated according to the material along its path. The energy-dependent material constant appearing in the exponent of this attenuation formula is called the linear attenuation coefficient. It expresses the amount of radiation that is attenuated on an infinitely small distance, in which the final attenuation reflects the sum of all these local linear attenuations along the X-ray beam. Therefore, an X-ray projection (or X-ray image) represents an image of the sum of all local attenuations along the X-ray beam.

To produce a three-dimensional CT image, a whole set of such two-dimensional projections need to be acquired. In microCT, these projections are usually taken in a setup in which the source and detector are at a fixed position and the object is rotated around its long axis (Figure 1). The source is mostly either a microfocus X-ray tube or an insertion device of a synchrotron radiation facility and the detector is normally based on a CCD camera with a phosphor layer to convert X-ray to visible light. Since CCD cameras have a limited number of pixels, the projections are recorded in discrete points with a so-called sampling distance (distance between neighboring pixels) and a maximal number of samples (which may correspond to the number of pixels on the CCD). It can be shown that the number of projections taken over 180 degrees should be about twice the number of samples per projection to avoid aliasing artifacts. The two-dimensional projections can then be used to reconstruct a three-dimensional image. In this sense, CT images can be seen as images that represent linear attenuation coefficients.[3]

CT provides high contrast because each pixel is assigned the value of the attenuation coefficient corresponding to one volume element, the image contrast is defined as the difference between the attenuation coefficients of two adjacent elements or areas of the image.

According to the Radon theory to obtain acceptable image quality, it is necessary to measure a sufficiently large number of integrated attenuation values (projections). These measurements must be made in all directions at least to the range angular from 0^0 to 180^0, where in each projection is necessary to obtain a plurality of data points with a short interval.[4]

For a more detailed consideration of options computed tomography is a block of cedar wood, which is seen in the 3D image (figure 2) and cross-sectional image (figure 3).

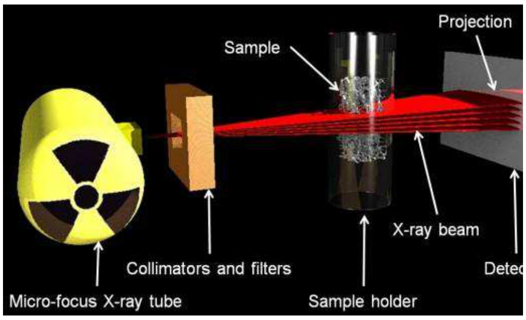

Figure 1: Main components and working principle of a microCT scanner. A micro-focus X-ray tube emits X-ray, which is collimated and filtered to narrow the energy spectrum. The X-ray passes then the object and is recorded by a two-dimensional CCD array. A full scan involves a set of projections under different rotations of the object.

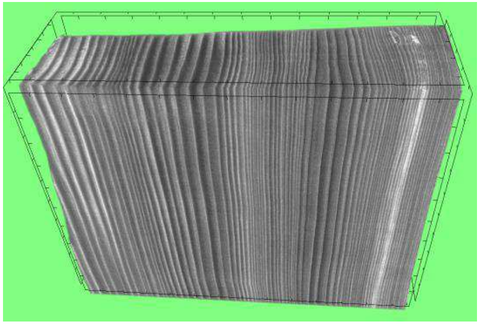

Figure 2: A block of wood in 3D image.

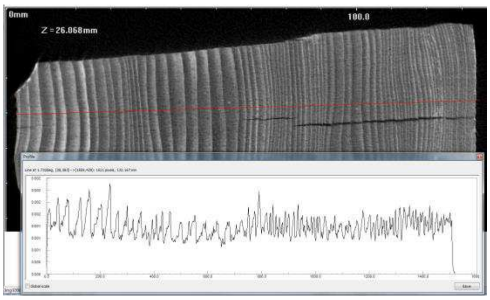

Figure 3: Wooden block sectional, plot of the intensity of the length of the bar on the red line.

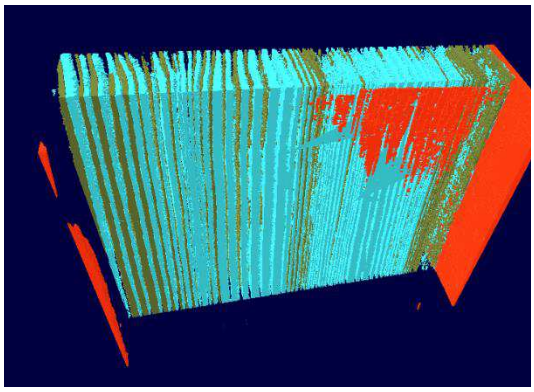

Figure 4: Wooden bar, which by means of the color gamut is distributed on different density equal. Red highlighted the minimum density that this case indicates air in green denotes the average density, blue - high density material.

Algorithms for Reconstruction with Nondiffracting Sources

A line integral, as the name implies, represents the integral of some parameter of the object along a line. There is a typical example is the attenuation of x-rays as they propagate through biological tissue. In this case the object is odeled as a two-dimensional (or three-dimensional) distribution of the x-ray attenuation constant and a line integral represents the total attenuation suffered by a beam of x-rays as it travels in a straight line through the object.

We will use the coordinate system defined in Fig. 3.1 to describe line integrals and projections. In this example the object is represented by a 2D function f(x, y) and each line integral by the (6, t) parameters.

The equation of line AB in Fig. 5 is

$$x \cdot cos\vartheta + y \cdot sin\vartheta = t \tag{1}$$

and we will use this relationship to define line integral P_ϑ (t) as

$$P_\vartheta(t) = \int_{(\vartheta,t)line} f(x,y)ds \tag{2}$$

Using a delta function, this can be rewritten as

$$P_\vartheta(t) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(x \cdot cos\theta + y \cdot sin\theta - t)dxdy \tag{3}$$

The function P_ϑ(t) is known as the Radon transform of the functionf(x, y).

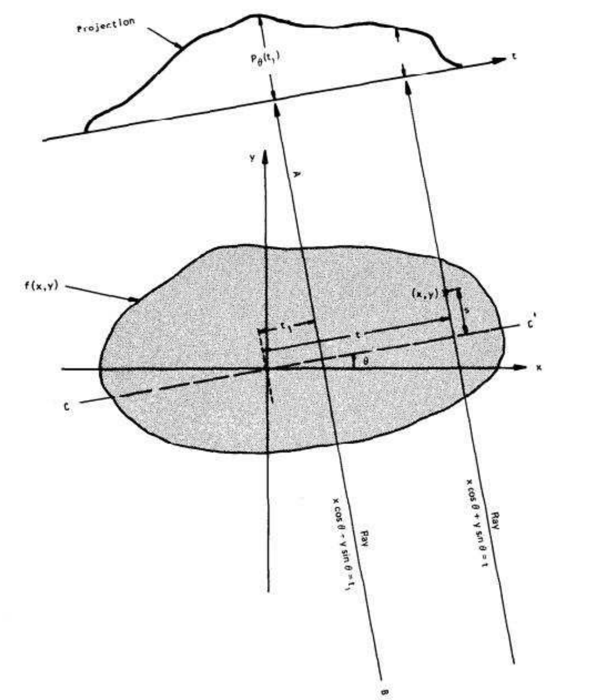

Figure 5: An object, f(x,y), and its projection, $P_\vartheta(t_1)$, are *shown for an angle of θ.*

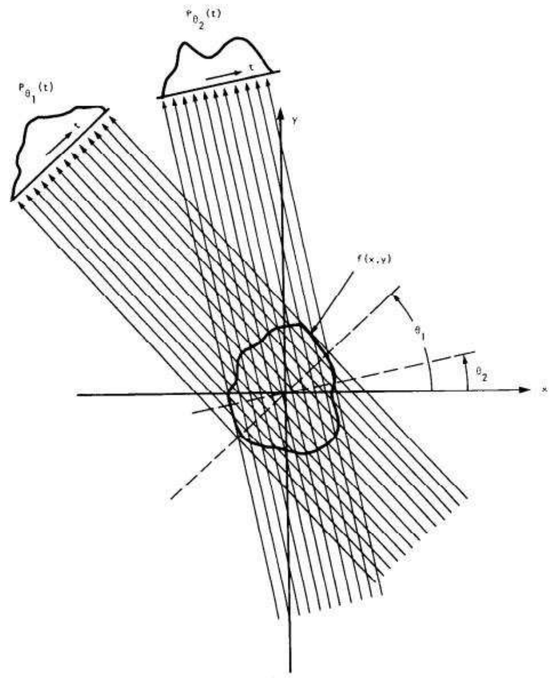

Figure 6: Parallel projections are taken by measuring a set of parallel rays for a number of different angles.

A projection is formed by combining a set of line integrals. The simplest projection is a collection of parallel ray integrals as is given by PO(t) for a constant 8. This is known as a parallel projection and is shown in Fig. 3.2. It could be measured, for example, by moving an x-ray source and detector along parallel lines on opposite sides of an object. [5]

Typical use

- Biomedical
- Electronics
- Microdevices
- Composite materials and metallic foams
- Polymers, plastics
- Diamonds
- Food and seeds
- 3-D imaging of foods using X-ray microtomography
- Wood and paper
- Building materials
- Geology
- porosity and flow studies
- Microfossils
- Space
- Stereo images

Conclusion

As a non-invasive method and by allowing to obtain data with a resolution of tens of nanometers to millimeters, microtomography becomes a breakthrough method for studying the structure and can significantly extend existing views and research in many fields of science and industry. The results of the study of various objects and materials as may be additional data to existing laboratory, and supplier of modern, not previously available information.[6]

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